

Leaf and Air Temperature under Hawaii Conditions

T. L. NOFFSINGER¹

AIR TEMPERATURE may give a poor indication of the actual temperature experienced by a plant leaf under various meteorological conditions. Leaf temperature is dependent upon the type and condition of the plant as well as on a number of meteorological elements including wind, humidity, cloud cover, solar radiation, and air temperature.

MATERIALS AND METHODS

During the period from March 9 through April 15, 1960, leaf and air temperatures were measured using a 12-channel single-input thermister-type thermometer. Leaf temperatures of pineapple and papaya plants were measured using a 22-gauge hypodermic probe. Air temperature was measured with the thermister air temperature probe and checked with a standard mercury-in-glass thermometer. The wet-bulb temperature was determined by a standard psychrometer and solar radiation was measured by a recording bimetallic actinograph (pyrheliometer).

Soil temperature was measured from a mercury-in-glass thermometer implanted 4 in. in the soil.

In measuring leaf temperatures the needle was carefully inserted from the underside of the leaf, parallel to the leaf veins, to approximately $\frac{1}{2}$ in.; i.e., at least $\frac{1}{2}$ in. of the probe was enclosed within the leaf tissue. All temperatures were read to the nearest 0.1° C. The average temperature of the plant was taken as the mean value obtained from one leaf exposed to solar radiation and one in shade.

RESULTS

Data were collected at 0800, 1200, and 1600 hr. during the period of March 9 through April 15. In addition, a continuous hourly collection was made over a 24-hr. period from 0800, April 11, through 0700, April 12.

¹ Climatologist, Land Study Bureau, University of Hawaii. Manuscript received May 19, 1960.

During the daylight hours pineapple leaf temperature was consistently higher than the air temperature measured in an instrument shelter at the same elevation as the plants. The values usually ranged from 1.5° to 3.5° C. above the air temperature but occasionally a leaf exposed to direct sunlight had a temperature as much as 7.6° C. higher than the air temperature.

The corresponding average temperature of the papaya leaf was consistently lower than the air temperature. Temperature of leaves exposed to direct solar radiation and temperature of leaves on the same plant but shaded by higher leaves are given in Table 1 together with the average air temperature, average leaf temperature, soil temperature, and solar radiation values.

Table 2 gives air temperature, leaf temperature, insolation values, soil temperature, cloud cover, and wind speed at 4-hr. intervals for a 24-hr. period April 11 through April 12. Maximum air temperature (27.0° C.) occurred at 1300; maximum soil temperature for the pineapple (28.0° C.) occurred at 1400; maximum soil temperature for the papaya (30.5° C.) occurred at 1500 and 1600. Maximum average leaf

TABLE 1
LEAF AND AIR TEMPERATURE AND
RELATED METEOROLOGICAL DATA FOR
MARCH 9–APRIL 15, 1960

TIME	0800	1200	1600
Air temperature $^{\circ}$ C.....	21.5	26.7	26.4
Leaf temperature $^{\circ}$ C.			
Pineapple			
average.....	23.2	29.1	26.6
in sun.....	24.7	31.0	28.0
in shade.....	21.7	27.2	25.2
Papaya			
average.....	21.3	25.4	24.5
in sun.....	21.7	25.9	24.9
in shade.....	20.9	24.9	24.1
Insolation Langleys/min..	0.21	0.99	0.74
Soil temperature			
Pineapple.....	19.5	26.4	26.3
Papaya.....	19.5	27.1	29.8

TABLE 2
LEAF AND AIR TEMPERATURE AND RELATED METEOROLOGICAL DATA
FOR 0800 APRIL 11–0800 APRIL 12, 1960

TIME	0800	1200	1600	2000	2400	0400	SUNRISE
Air temperature °C.....	22.0	25.7	26.7	22.3	22.2	21.9	22.0
Leaf temperature °C.							
Pineapple							
average.....	23.5	29.5	27.1	21.7	21.5	22.1	21.7
in sun.....	25.0	31.5	29.0	.....	.....	.....	.....
in shade.....	21.9	27.5	25.1	21.7	21.5	22.1	21.7
Papaya							
average.....	21.3	25.1	24.8	21.2	20.5	21.0	21.7
in sun.....	21.6	25.0	26.0	.....	.....	.....	.....
in shade.....	21.0	25.1	23.5	21.2	20.5	21.0	21.7
Insolation							
Langleys/min.....	0.27	1.43	0.98	.....	.....	.....	.....
Soil temperature							
Pineapple.....	20.2	26.5	27.0	23.7	21.4	21.4	20.5
Papaya.....	20.5	27.0	30.5	24.2	21.2	21.2	20.5
Cloud cover (1/8 S.).....	5	6	1	1	1	5	1
Wind (knots).....	8	8	10	5	4	0	0

temperature in the pineapple plant (29.6° C.) occurred at 1500 and in the papaya plant (26.8° C.) at 1300.

DISCUSSION

Plants undergo irradiation from the sun, clouds, and sky during the daylight hours, and at night they radiate heat outward. Mäde (Geiger, 1950: 278–280) kept a continuous record of leaf temperature over a period of two days and found that during the middle of the day the leaf surface of *Bilbergia nutans* (a hothouse plant of the pineapple family) was as much as 10° C. higher than the air temperature. The interior portion of the pineapple fruit exposed to the direct rays of the sun at latitude 21° N. may experience temperature from 5° to 8° C. above the free air temperature. In Formosa it has become a practice to shade the pineapple fruit in order to prevent heat damage from solar radiation (Ekern, personal communication). Waggoner and Shaw (1952) have shown that energy losses from potato and tomato plants at night due to transpiration may be very small. Geiger (1950: 276) states that plant temperature is generally higher than that of air temperature when the ground surface is warmer than the air layer resting upon it, and that by night the plant is, for the most part, cooler than the air.

An examination of air, soil, and leaf temperatures in Tables 1 and 2 shows that the generalization made by Geiger holds for pineapple, but that the average leaf temperatures of the papaya were consistently lower than the air temperature even during periods of relatively high soil temperature. In one observation during the period (not shown in the table), the temperature of the papaya leaf exposed to the sun registered 2.6° C. higher than the air temperature. At that time the value for solar radiation was 1.42 calories per sq. cm. per min., the sky was five-eighths covered with cumulus and stratocumulus clouds and a light sprinkle of rain was falling from clouds immediately to the N.E. of the station.

SUMMARY

Air temperature in an instrument shelter at the level of the plants does not provide a good measure of plant temperature. Papaya, with a respiration and transpiration pattern characteristic of the mesophytes, shows a leaf temperature which remains relatively near the air temperature but may be higher or lower than the air temperature, depending upon the condition of radiation, cloud cover, and wind. Pineapple, a xerophyte, has leaf temperature during the daylight hours which average 1.5° to 3.5° C. above

the air temperature, and for short periods of high solar radiation a leaf temperature 7.6° C. above the air temperature was recorded. Generally, leaf temperatures of both pineapple and papaya were below the air temperature during the night except for one period in which clouds moved into the area. At 0400, April 12, with five-eighths cloud cover and calm wind, the temperature of the pineapple leaf rose to 0.3° C. above the air temperature.

REFERENCES

- EKERN, P. C. Personal communication.
- GEIGER, R. 1950. *The Climate Near the Ground*. Harvard Univ. Press, Cambridge. P. 276.
- WAGGONER, P. E., and R. H. SHAW. 1952. Temperature of potato and tomato leaves. *Plant Physiol.* 27: 710-724.